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(72) Inventor(s): <b>Brian Hilton Brown</b> <b>John Anthony Tidy</b>	 (58) Field of Search: UK CL (Edition X ) A5R, G1N INT CL <sup>7</sup> A61B, G01N Other: Online: WPI, EPODOC.		
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(54) Abstract Title: **Body tissue impedance measuring probe with wireless transmitter**

(57) A probe 16 for measuring the electrical impedance of human or animal body tissue comprises a housing 18 and at least two electrodes 20 mounted on the surface of the housing 18. Contained within the housing 18 are: a current source coupled to the electrodes, a controller to control the current source to drive a current between the electrodes, a voltmeter to measure potential difference between the electrodes, and a communication circuit for wirelessly transmitting the measured potential difference to a remote device. The probe may also include a processor to calculate tissue impedance from the measured potential difference, in which case the communication circuit transmits the calculated impedance. Wireless telemetry may be via an optical or radio frequency (RF) connection, for example using an infra red transmitter 22. The transmission of data without the use of a wired connection improves measurement accuracy due to the removal of the parasitic capacitances arising from cable connections. The probe may be used for cancer screening. A method of measuring impedance is also disclosed.

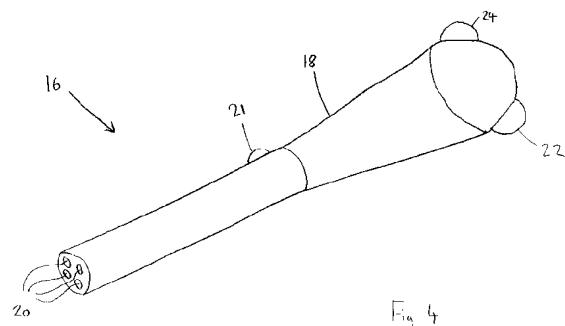


Fig. 4

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995. At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig. 1

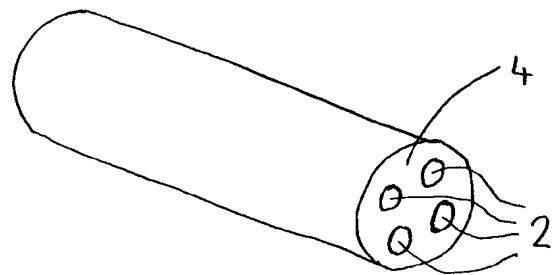
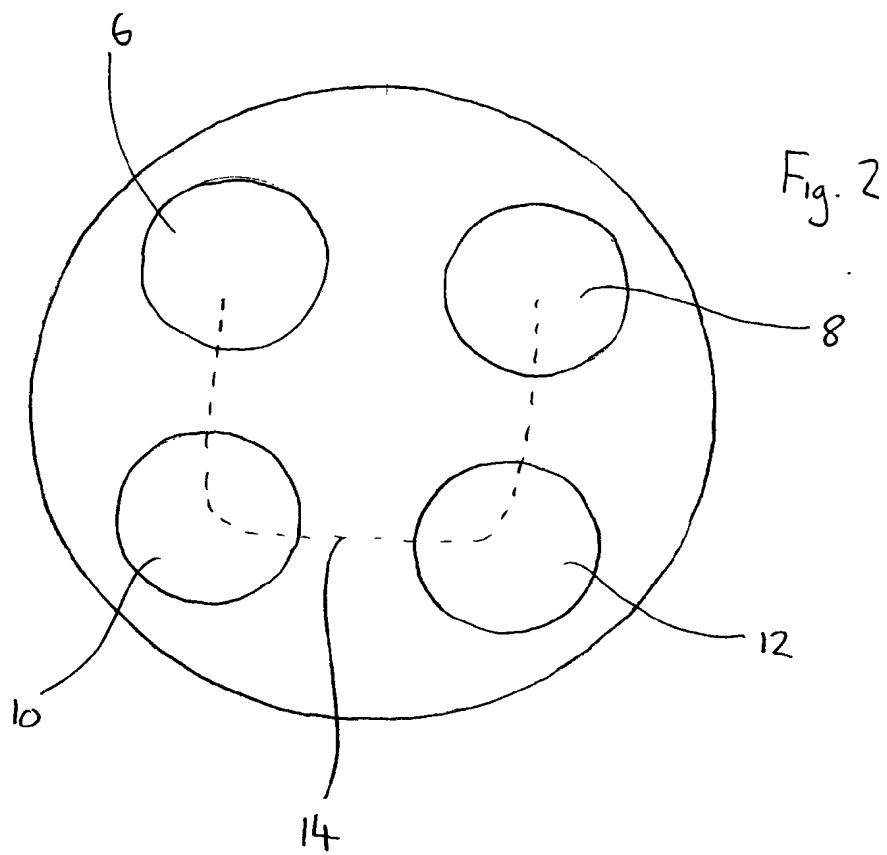


Fig. 2



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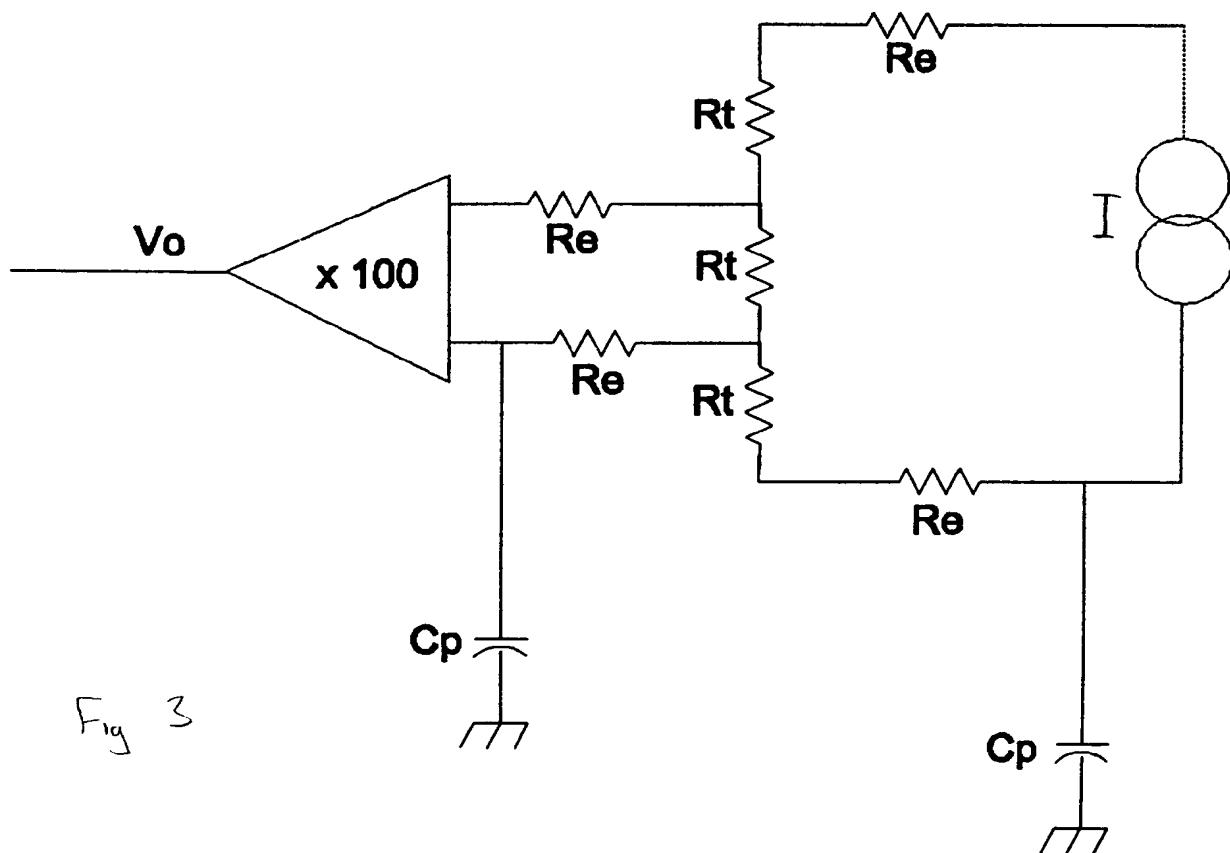


Fig 3

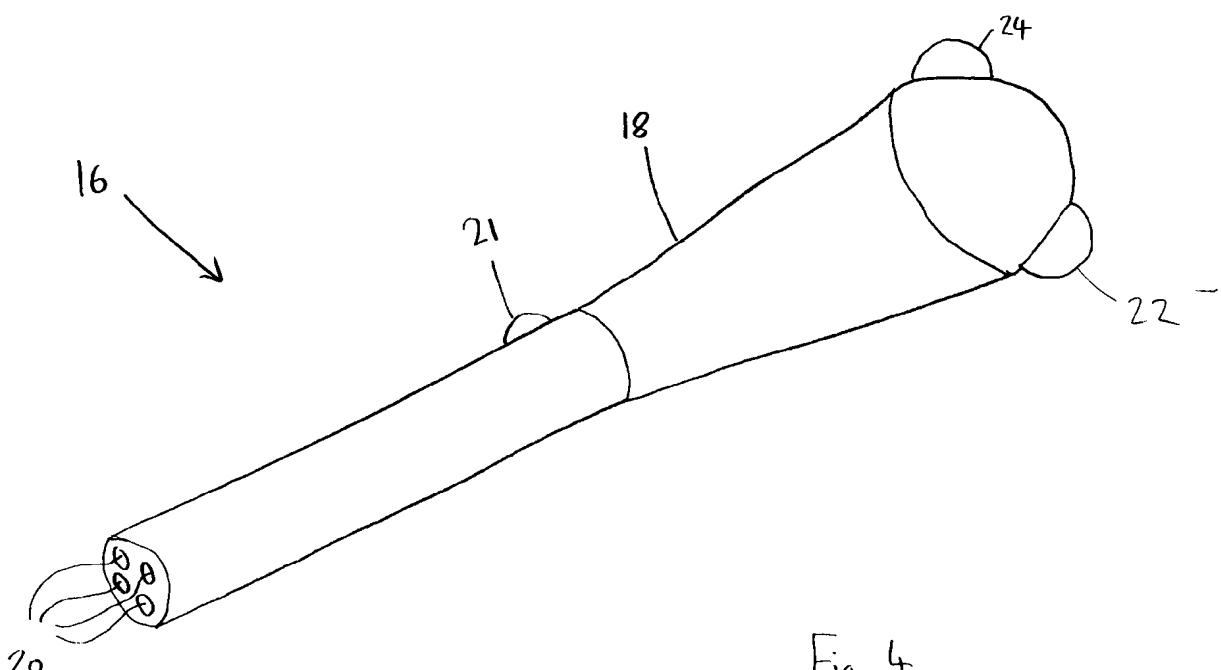


Fig 4

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METHOD AND PROBE FOR MEASURING THE IMPEDANCE OF HUMAN OR  
ANIMAL BODY TISSUE

The present invention relates to a method and probe which can measure the impedance of human or animal body tissue and in particular to a method and probe which can improve 5 the accuracy of the results obtained.

It has been proposed to use measurements of tissue impedance in medical diagnosis applications. An example of a probe suitable for measuring the tissue impedance is discussed in WO-A-01/67098 and is depicted in Figure 1. The probe comprises four 1mm diameter gold electrodes 2 which are mounted flush with the end face 4 of the probe and 10 spaced equally on a circle of 1.65mm radius.

Figure 2 depicts the way in which the probe is used to calculate a transfer impedance when it has been placed in contact with a tissue to be measured. An ac current  $I_1$  of 10  $\mu$ A peak-to-peak is passed between two adjacent electrodes 6,8 and the real part of the resulting potential  $V_1$  between the two remaining electrodes 10,12 is measured. The current path 15 used for measuring the impedance is depicted in Figure 2 by broken line 14, it runs from electrode 6 to electrode 10 to electrode 12 to electrode 8.

The ratio of the measured potential to the amplitude of the current determines the transfer 20 impedance. Measurements are made at eight frequencies by doubling the frequency in steps between 4.8 kHz and 614 kHz. Measurements may also be made at frequency ranges with an upper limit of up to 1.5 MHz.

The transfer impedance so measured can then be analysed for use in cancer screening because the value will vary according to the type of cells and their arrangements which make up the tissue. The transfer impedance can also be used in screening for pre-term birth.

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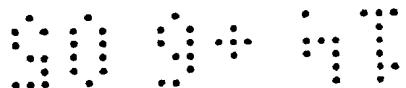
WO-A-2004/098389 discusses devices and methods for bioimpedance measurement. It describes a probe which is connected by a wired connection to an electrical signal generator.

It is desirable to improve the accuracy of the measured transfer impedance. In accordance  
5 with the present invention a probe for measuring the impedance of human or animal body tissue includes a transmission circuit for transmitting the results obtained by the use of the probe for processing by a second device without using an electrical wire.

It has been found that a significant source of error in the measurements obtained arise from  
10 the presence of parasitic capacitances. In particular, it has been identified that the use of an electrical wire to connect the probe to another device, such as a signal generator to generate the applied signals or a computer system for processing the data obtained, introduces parasitic capacitance and reduces the accuracy of the measurements taken. Given the relatively small currents and high frequencies used in the system, the additional parasitic capacitance can have a significant effect on the accuracy of the results. By transmitting the  
15 results without using an electrical wire parasitic capacitances associated with the wire can be eliminated and the accuracy improved.

According to a first aspect of the present invention, there is provided a probe for measuring the impedance of human or animal body tissue; the probe comprising:

- 20 a housing;
- at least two electrodes mounted on an external surface of the housing;
- 25 a current source coupled to the at least two electrodes;
- a voltmeter for measuring a potential difference between the at least two electrodes;
- a controller for controlling the current source to drive a current between the at least two electrodes; and
- 25 a communication circuit for transmitting the measured potential difference to another device without using an electrical wire;
- wherein the current source, voltmeter, controller and communication circuit are contained within the housing.



The term voltmeter is used to mean a circuit which is capable of measuring the potential difference between two points. By transmitting the data without using an electrical wire, parasitic capacitance is reduced and the accuracy of the measurements taken is improved.

5 Preferably, the probe further comprises a processor for calculating the impedance of tissue between and in contact with the electrodes using the output of the voltmeter; and wherein the communication circuit is for transmitting the calculated impedance. The impedance can be calculated using the ratio of the measured potential to the amplitude of the current.

10 In one embodiment the communication circuit is an optical transmitter circuit. The optical transmitter circuit may comprise an Infrared transmitter. The optical transmitter may be for communication with a corresponding receiver using a fibre-optic cable. Optical communication techniques are beneficial because the signal is less likely to be subject to interference or to interfere with other signals.

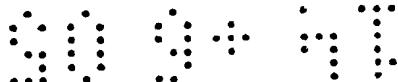
In another embodiment the communication circuit is a wireless RF transmitter circuit.

15 The communication circuit may conform to a known communication standard such as Bluetooth, wireless ethernet or IRDA. This would have the advantage that the probe could communicate easily with a second device without requiring specialist hardware in the second device.

According to a second aspect of the present invention, there is provided a method of measuring the impedance of human or animal body tissue, the method comprising:

20 applying an alternating current between two electrodes;  
measuring a resulting potential difference; and  
transmitting the measured potential difference without using an electrical wire to a second device for processing.

25 Preferably, the method further comprises calculating the impedance using a ratio of the amplitude the alternating current to the measured potential difference; and wherein in the step of transmitting the calculated impedance is transmitted.



Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 depicts a probe for measuring the impedance of tissue;

5 Figure 2 depicts a method for using the probe depicted in Figure 1 to measure the impedance of tissue;

Figure 3 depicts an equivalent circuit of a wired probe; and

Figure 4 depicts a probe according to an embodiment of the present invention.

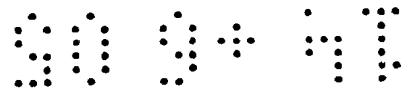
10 Figure 3 illustrates a simplified equivalent circuit of the probe of Figure 1 used in accordance with the method depicted in Figure 2 to measure the impedance of tissue when the probe is connected to a data processing device using a wired link.

It has been found that a significant source of error in impedance measurements of body tissue is parasitic capacitance arising from the use of a wired connection to the probe.

15 Figure 3 illustrates a simplified equivalent circuit of the probe of Figure 1 used in accordance with the method depicted in Figure 2 when the probe is connected to a data processing device using a wired link.

20 In Figure 3, the output voltage is denoted  $V_O$ , the electrode impedances are denoted  $R_e$ , the resistances of the tissue with which the probe is in contact are denoted  $R_t$  and the parasitic capacitances arising from the wired connection are denoted  $C_p$ . Only two parasitic capacitances are depicted in Figure 3, in reality there will be more, but for simplicity only two are shown. A current source  $I$  provides an a.c. current.

25 The parasitic capacitances  $C_p$  arise between the components of the probe and the wiring used to connect to the second device, for example a computer. Ultimately the connecting wires are connected to ground via the ground connection of the computer. This results in further parasitic capacitances between the probe components and the ground and between the wiring and the ground.



As discussed above the impedance measurement of tissue is carried out at a variety of frequencies. These frequencies can extend from 500 kHz up to 3 MHz at their upper limit. As the frequency is increased the effect of the parasitic capacitances becomes a significant component of the output voltage  $V_o$ .

5 An example of the effect of parasitic capacitances will now be discussed. If it is assumed that measurement is taken at a frequency of 2 MHz and the values of the components in the equivalent circuit of Figure 3 are as follows:  $R_e = 10 \text{ k}\Omega$ ;  $R_t = 50 \Omega$ ;  $I = 20 \mu\text{A}$ ; and  $C_p = 5 \text{ pF}$ , the output  $V_o$  will be 112.8 mV. (The values assumed are typical to those found in practice when the probe is used for cervical cancer screening.) This compares with an  
10 output voltage of 100 mV when the parasitic capacitances are ignored in the calculation. Therefore, the presence of the parasitic capacitances cause an error of more than 10% in the output  $V_o$ .

15 It is possible that the parasitic capacitances may have values larger than the 5pF assumed in this calculation, or that there will be additional parasitic capacitances. This would result in a larger error in  $V_o$ .

20 A first embodiment of a probe 16 for measuring the impedance of body tissue according to the present invention is depicted in Figure 4. All the circuitry of the probe 16 is contained within a housing 18 of the probe. Four electrodes 20 are provided in the distal end of the housing arranged at the corners of a square as described above. A button 21 is provided on the housing 18 which when pressed by an operator results in the probe measuring the  
25 impedance of the tissue with which the electrodes 20 are in contact.

The housing 18 contains a power source (a rechargeable or replaceable battery, not shown) connected to circuitry for taking an impedance measurement of the tissue. This circuitry includes a current source for driving a current between two adjacent electrodes and a  
25 voltmeter for measuring a potential difference between the other two electrodes.

The probe 16 measures the tissue impedance by driving the electrodes in the same way as that described in WO-A-01/67098. That is, an alternating current is driven between two



adjacent electrodes and the resulting potential difference is measured between the other two electrodes. The ratio of the amplitude of the alternating current to the resulting potential difference can then be used to calculate the tissue impedance. The amplitude of the alternating current may be in the range 1  $\mu$ A to 1 mA. Measurement is taken at several 5 values in the range of 1 kHz up to an upper limit of 500 kHz to 3 MHz.

The probe 16 of this embodiment reduces the parasitic capacitance by providing a transmitter circuit (not illustrated) within the housing of the probe which can transmit the data without using an electrically conductive wire. In this embodiment an infrared (IR) transmitter circuit is used. The probe includes an IR transmitter 22 which can transmit 10 information to a receiver on a computer for processing. The use of the IR transmitter 22 reduces the chance of interference on the transmitted signal itself and also of the transmitted signal interfering with other signals.

By removing the electrically conductive connecting wire, all the stray capacitances associated with the connecting wire and its connection to ground are removed, improving 15 the accuracy of the measurements taken. As discussed above, this can result in an improvement in accuracy of more than 10% compared to a wired system when measurements are taken at a frequency of 2 MHz.

The use of an IR transmitter 22 in this embodiment requires a line of sight to a receiver which may not always be possible when the probe 16 is in use. The probe 16 therefore 20 includes a memory which can store one or more measurements taken by the probe 16. After the measurements have been taken, the probe 16 can then be moved to a location where it is in the line of sight of an IR receiver and the results transmitted. The operator can start transmission of the results by pressing a transmission button 24.

In this embodiment the data is transmitted to a computer, although it may instead be 25 transmitted to any device which can process and/or display the data.

In an alternate embodiment the probe also includes a processor to calculate the transfer impedance of the tissue before the results are transmitted. This reduces the processing to be carried out on the data when it has been transmitted from the probe.

5 In further alternate embodiments other forms of communication circuit may be used. For example a fibre-optic cable link may be used, or a wireless RF transmitter. In these alternate embodiments a line of sight to a receiver is not required and the transmission data to cause the probe to transmit the data may be omitted.

10 In still further embodiments of the invention a different number of electrodes may be provided, provided that there are at least two electrodes between which a current can be driven.

CLAIMS

1. A probe for measuring the impedance of human or animal body tissue; the probe comprising:
  - a housing;
  - 5 at least two electrodes mounted on an external surface of the housing;
  - a current source coupled to the at least two electrodes;
  - a voltmeter for measuring a potential difference between the at least two electrodes;
  - 10 a controller for controlling the current source to drive a current between the at least two electrodes; and
  - a communication circuit for transmitting the measured potential difference to another device without using an electrical wire;
  - 15 wherein the current source, voltmeter, controller and communication circuit are contained within the housing.
2. A probe according to claim 1, further comprising a processor for calculating the impedance of tissue between and in contact with the electrodes using the output of the voltmeter; and wherein the communication circuit is for transmitting the calculated impedance.
3. A probe according to claim 1 or 2, wherein the communication circuit is an optical transmitter circuit.
4. A probe according to claim 3, wherein the optical transmitter circuit comprises an Infrared transmitter.
5. A probe according to claim 3 or 4, wherein the optical transmitter is for communication with a corresponding receiver using a fibre-optic cable.
- 25 6. A probe according to claim 1 or 2, wherein the communication circuit is a wireless RF transmitter circuit.

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7. A method of measuring the impedance of human or animal body tissue, the method comprising:

applying an alternating current between two electrodes;

measuring a resulting potential difference; and

5 transmitting the measured potential difference without using an electrical wire to a second device for processing .

8. A method according to claim 7, further comprising calculating the impedance using a ratio of the amplitude of the alternating current to the measured potential difference; and wherein in the step of transmitting the calculated impedance is transmitted.

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**Application No:** GB0511290.9

**Examiner:** Eleanor Hogan

**Claims searched:** 1-8

**Date of search:** 13 October 2005

## Patents Act 1977: Search Report under Section 17

### Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X, Y	X: 1, 2 & 6-8; Y: 3-5.	US 4784155 A (MILLS) see abstract, col. 2 line 48 - col. 3 line 59 and figs.
X, Y	X: 1, 2 & 6-8; Y: 3-5.	US 6360123 B1 (KIMCHI et al) see abstract, col. 5 line 6 - col. 6 line 13, col. 9 lines 28-45, and figs. 1-3 & 4E.
X, Y	X: 1, 2 & 6-8; Y: 3-5.	EP 0344770 A1 (STATE OF ISRAEL) see abstract, cols. 5, 6 9 & 10 and fig. 1.
Y	1, 2 & 6-8.	WO 2004/105270 A1 (HEALTHPIA) see abstract and figs. 2 & 3.
Y	1-4, 7 & 8.	US5372141 A (GALLUP et al) see abstract, col. 4 lines 4-22, cols. 5 & 6 and figs.
Y	1, 2, 6, 7 & 8.	WO 00/28892 A1 (MICROMEDICAL) see abstract, pages 4, 8 & 9 and figs. 4, 7, 8 & 10.
Y	1 & 7 at least.	WO 01/67098 A1 (BTG INTERNATIONAL) see abstract, page 11 and figs.
Y	1 & 7 at least	WO 2004/098389 A2 (JOHNS HOPKINS UNIVERSITY) see abstract, pages 21-23 and figs.
Y	5	GB 2195897 A (ST MARY'S HOSPITAL) see abstract, page 3 lines 1006-113 and fig. 6.

### Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date



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earlier than, the filing date of this application.

**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>X</sup> :

A5R; G1N

Worldwide search of patent documents classified in the following areas of the IPC<sup>07</sup>

A61B; G01N

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC.